V.—Woodwardian Museum Notes: on some Anglesey Dykes. I.

By Alfred Harker, M.A., F.G.S.,
Fellow of St. John's College.

IN the Woodwardian Museum is a collection of nearly a thousand rock-specimens made by Professor Henslow to illustrate his "Geological Description of Anglesea" (1821, Trans. Camb. Phil. Soc. vol. i. pp. 359–452, plates xv.–xxi.). Specimens of the principal dykes were submitted to the examination of Professor Cordier, and his remarks on them are quoted in Henslow's paper. As Cordier's determinations date from a time when thin slices of rocks were unknown, and but little attention has since been given to the dykes of Anglesey, it is believed that brief notices of some of the typical rocks from localities easily identified may have an interest for British geologists. As regards the mode of occurrence of the dykes and their effects upon the adjacent strata, little can be added to the accurate descriptions of Henslow, written at a time when the igneous origin of dykes was a proposition to be proved. The specimens are referred to by number in the memoir, and these numbers will be cited below in brackets [ ].

We begin with a few specimens from the numerous dykes exposed on the shores of the Menai Straits. In spite of some interesting variations, these rocks possess many characters in common. They strike usually in directions varying from S.E. to E.S.E., and often coincide with lines of faulting, which are at right angles to the general strike of the strata. The only direct evidence of their date of intrusion is that they sometimes cut through Carboniferous beds; but if it is allowable to correlate these dykes with others having a similar direction in the Anglesey Coal-field, we may infer from Sir A. Ramsay's reasoning that the whole are of pre-Permian age (Geology of North Wales, 2nd ed. p. 264).

Beginning near Beaumaris, we find in the green contorted schists between Gallows Point and Garth Ferry an enormous number of small dykes of generally compact appearance. The majority of them are not more than a foot or two in breadth, but some attain to about twenty feet. They frequently ramify, but show on the whole a parallel arrangement with an average bearing about S.E. by E. In some cases a certain relative movement of the rocks on opposite sides of a dyke can be verified. Making allowance for the varying sizes of the dykes and the modifications due to more rapid cooling near the edges, the rocks present a general community of megascopic characters; only two of Henslow's specimens have been selected for closer examination.

Dykes between Gallows Point and Garth Ferry.

[640.] Augite-andesite.—The hand-specimen shows a black, compact ground-mass containing numerous clear felspars in the form of parallelograms. These crystals are very flat, and have a marked parallel arrangement, as noticed by Cordier and Henslow. Under the microscope they are seen in cross-sections of elongated shape, 0·1 to 0·15 inch in length, and their fluxional arrangement is very

evident. The faces which give the felspars their tabular habit are the brachypinacoids, while the other forms present may be the macropinacoid and basal planes. The usual albite-twinning is seen, combined with the Carlsbad type: the extinction-angles seem to indicate labradorite. The crystals are often bent and partially fractured, but I have not observed any relation between these disturbances and the twin-lamellation. Besides the felspars are abundant crystals of magnetite; and the ground-mass is composed of felspar microlites, magnetite, and rounded granules of augite decomposing into a pale-green substance. In both the ground-mass and the larger constituents, the magnetite seems to be of rather earlier formation than the felspar.

[642.] Augite-andesite.—Henslow mentions this rock as "more remarkably fine-grained and tough than any other which I have met with in Anglesea." It is a contact specimen with a fragment of the green schist firmly adhering to it. Here the scattered felspars are smaller and occur more sparsely; they show little of the tabular habit and parallel disposition so striking in the preceding slide. The ground-mass too is a little finer; but with these exceptions the same description will suffice.

To illustrate the modifications of texture in different parts of one dyke, two specimens collected by Prof. Hughes have been sliced, They are from a dyke just south-west of Gallows Point.

Augite-andesite from marginal portion of dyke.—This is intermediate in texture between [640] and [642], and has the same general characteristics. The scattered felspars, however, have inclusions of magnetite, disposed chiefly along the twin-planes.

Dolerite from central part of the same dyke.—The slide exhibits rectangular sections of felspar, mostly lath-shaped and about 0·1 inch in length, magnetite in crystals giving quadrangular sections and in rods, and decomposed augite in ophitic plates. There is no ground-mass. The felspars show twinning by different laws. In some cases a crystal is divided by a line which may represent Carlsbad twinning into two halves, of which one shows lamellation on the albite and the other on the pericline type. The lamellæ are often interrupted.

Another of Prof. Hughes' specimens, from a dyke north-east of Garth Ferry House, may be styled a porphyritic dolerite.—This rock bears a close resemblance to the preceding, but differs from it in the fact that the magnetite occurs in imperfect crystals of later formation than the felspar. Besides the rectangular felspars there are a few of larger dimensions giving squarish sections. This rock shows more advanced decomposition than the others mentioned above. The augite, which appears to have formed ophitic plates, is entirely destroyed and replaced by the usual pale-green substance with confused scaly structure, and polarizing in low tints of grey and indigo. Patches of this 'viridite' inclose crystalline grains of calcite. Grains of secondary quartz are also plentiful, as well as magnetite dust and ferruginous specks. The felspars are almost opaque.

Cordier pronounced some specimens from this part of the Straits to be "dolerite. The pyroxene very evident, with *fer titané*." In the slides examined, however, the iron-ores never show forms characteristic of ilmenite, and no leucoxene occurs. The compact rocks are named "basaltic lava."

Cadnant dyke.—Between Garth Ferry and Menai Bridge we meet with the first large dyke, which occurs on the right bank of the little stream at Cadnant. This dyke is not marked on the Maps of the Geological Survey, but Henslow traced its course among the schists for some distance inland. He also found it on the Carnarvonshire shore, where it cuts Carboniferous strata. In the latter place the rock is less compact in texture than on the Anglesey side, and Henslow states that "none of the dykes which intersect the limestone and shale attain to so great a degree of compactness as the generality of those which are found among the schist." Three dykes having a similar strike to that at Cadnant are marked on the Survey Map south of Bangor Station, and a slide from one of these, at Glan Adda, has been examined. Cordier identified the Cadnant rock as "a true dolerite, having the ingredients, pyroxene, *fer titané*, and felspar well characterized."

[545.] Dolerite; a typical specimen from Cadnant.—To the eye the rock shows a moderately coarse-grained aggregate, in which the augites are conspicuous, moulding elongated crystals of felspar. Under a low objective the structure is seen to be holocrystalline and ophitic. The felspars occur in mostly elongated sections, showing a rather fine albite-twinning, combined with a concentric zonary banding, and sometimes twinning on the pericline law. From the extinction-angles they should be andesine or oligoclase. This rock exemplifies a character found in most other similar dykes in North Wales; the felspars appear to be of two generations, of which one is older, and the other newer than the bulk of the magnetite. The later felspars are distinguished by their imperfectly defined outline and more equal dimensions, their more marked zonary banding, and their greater clearness: their twin-lamellæ are usually very narrow and rather wide apart. A few prisms of apatite are seen. The magnetite in this slide is plentiful, and builds crystals of intricate branching shapes. The augite has the pale-brown tint common to that mineral in almost all North Welsh rocks. It moulds the other constituents, and never shows crystal boundaries. The prismatic cleavages are strongly marked, and there are ill-defined interpositions arranged in branching lines or planes. The chief secondary product is a yellowish-green, doubly refracting mineral, which pseudomorphs augite: secondary granular magnetite accompanies it in places. The dominant felspar is often almost opaque owing to alteration-products.

Porphyritic dolerite: Glan Adda, south of Bangor Station.—This dyke occurs on the same line as that at Cadnant, and may be briefly referred to for comparison. Here the earlier felspars have lath-shaped sections: the later ones are more equi-dimensional, and show the zones of different chemical composition very distinctly. The augite moulds the older felspars, but is of earlier formation than the

second generation, and sometimes shows crystal-outlines, the prism and pinacoidal planes. Iron-ores are abundant, chiefly magnetite; fine needles of apatite occur in the felspars; small scattered flakes of biotite are sparsely present. The latter mineral is met with in the Cadnant dyke [525], "a circumstance of rare occurrence in the dykes of Anglesea," (at least in those of the Menai Straits). The Glan Adda dyke has pink porphyritic felspars, which under the microscope show large squarish sections, much decomposed.

It will be noticed that all these dolerites correspond in character more closely to the andesitic than to the basaltic family: olivine I have not yet observed in the above rocks, though it may possibly be lost among the decomposition-products. This mineral occurs, however, in the Plas Newydd dyke described below.

[546.] Dolerite: near Four Crosses, on the north-western prolongation of the Cadnant dyke.—This specimen, to illustrate the more compact type of rock, is taken from the outer portion of the dyke, though not from the actual contact, where the andesitic *habitus* prevails. The magnetite is mostly older, but partly newer, than the felspar; it occurs in crystals showing the cube or octahedron, and in complex shapes related to those forms. The minuter grains often appear in star-like aggregates with sections exhibiting three bilobate rays: these are sometimes surrounded by a ring of finely granular magnetite. The felspars give elongated rectangular sections: the larger ones are often simple or once twinned, but fine twin-lamellation is also found. The pale-brown augite, in ophitic plates of varying extent, is mostly destroyed. As secondary products occur the usual "viridite," finely granular calcite, and clear quartz.

The dykes in the neighbourhood of Menai Bridge have not been sliced. They are dolerite, often with porphyritic felspars. They appear to be much decomposed, and contain a considerable amount of calcite and pyrites.

Plas Newydd dyke.—The largest dyke in this part of the island cuts through the lower beds of the Carboniferous Limestone series a little south of Plas Newydd, the seat of the Marquis of Anglesey. This dyke, 134 feet wide, occupies a probable line of fault bearing in a south-easterly direction: it is met with again on the opposite side of the Straits. In the nomenclature of Cordier's day the rock was described as "indubitable basalt, consisting of felspar and pyroxene," but the normal type is holocrystalline and granular.

[485.] Olivine-Dolerite; typical rock of the Plas Newydd dyke; a rather coarse-grained dolerite with marked ophitic structure.—The microscope reveals olivine in abundant rounded grains included in the augite. There is much secondary magnetite dust resulting from its decomposition. Magnetite occurs also in crystals, usually imperfect cubes; this and the olivine are the earliest formed constituents. The chief felspars are in elongated crystals showing finely repeated twinning and often concentric zoning; the extinction angles are moderately high, and would agree with labradorite. There is some slight bending of the crystals, which may perhaps affect the twin-lamellation. Sometimes cross-twinning, presumably on the pericline

law, is observed. There is also, as in the Cadnant dyke, a later generation of felspars, shapeless, but broader than the others. They are simple or once twinned, and between crossed Nicols show strong zonary shading: as usual they are clearer than the earlier felspars. The augite is in light-brown plates, moulding the dominant felspars: it shows branching layers of interpositions. The chief secondary products in this slide are a yellowish-green structureless substance and a ferruginous staining; both seem related to the augite.

[486.] Dolerite; the more compact portion of the dyke; a fine-grained ophitic rock with abundant magnetite, closely resembling [546] from the Cadnant dyke. The felspar is in elongated prisms, with mostly repeated albite-twinning and fairly wide extinction-angles. It is clear except for some granular calcite and fine viridite strings, following for the most part, the basal cleavage-cracks. Magnetite is plentiful in crystals, skeletons, and rods; and is slightly posterior to the felspar. The apparent rods, which are probably sections of plates, have a parallel disposition, and are arranged transversely to felspar crystals which they surround. A similar relation of magnetite to olivine is described by Reusch from the basalts of Jan Mayen.[1] The present rock contains also minute rings (spherical shells) of magnetite dust surrounding nuclei of the same. The augite, always allotriomorphic, has the same characters as in the preceding slide. Chloritic decomposition-products and clear secondary quartz occur.

The metamorphic effects of the Plas Newydd dyke upon the adjacent Carboniferous strata, as described by Henslow, possess considerable interest. On the south-west side a bed of calcareous shale, abutting upon the dyke, is converted into a kind of lydianite, containing calcite and clusters of garnet and analcime crystals. Henslow's specimens [511 to 523] show the development of these last-named minerals in every stage from mere whitish concretionary spots in the hardened shale to perfectly formed crystals. These are closely clustered together along particular bedding-planes, and sometimes the valve of a *Productus*, converted into crystalline calcite, is seen to be studded over and penetrated by globules or crystals of analcime.

The garnet occurs in crystals up to 0·7 inch in diameter, showing the faces of the rhombic dodecahedron (110), sometimes truncated by narrow planes belonging to the form (211): they have often a marked concentric zonary structure. They vary from yellowish-green to olive-brown, with a resinous lustre. "Their specific gravity is 3·353," and their hardness under 7. These characters indicate a variety approaching *grossularia*; Lyell[2] gives the percentage of lime as 20. A slice (cut from a specimen in the Sedgwick collection) shows a number of crystals in various stages of development, closely packed together, and the interstices filled with crystalline calcite. The crystals are not all isotropic: they contain a large amount of foreign material. The readiness with which garnets of considerable

[1] Cf. also Prof. Judd's basalt from Mull, Q.J.G.S. vol. xlii. pl. vi. fig. 7, 1886.
[2] Student's Elements of Geology, 3rd ed. p. 515.

size are formed by contact alteration is evidently connected with this capacity of the mineral for including in its crystals a large quantity of foreign matter. The same remark applies to disthene and chiastolite.

The analcime crystals, where they are best developed, show the faces of the trapezohedron (211), and have a concentric zonary structure. The specimens were analyzed by Cumming, who pronounced them to be "analcime with excess of iron." His figures, however, differ widely from published analyses of the mineral in question, and can only be reconciled by supposing the analcime to be partially changed into prehnite, a mode of alteration known to take place occasionally.[1] Assuming the iron to be present as ferric oxide, and replacing it by alumina, Cumming's analysis is represented by column I. below. The second column gives the composition of analcime calculated from the formula $H_4 Na_2 Al_2 Si_4 O_{14}$; the third prehnite from the formula $H_2 Ca_2 Al_2 Si_3 O_{12}$. Column IV. is the mean of II. and III.

	I.	II.	III.	IV.
Silica	49	54·4	43·6	49·00
Alumina	24	23·4	24·9	24·15
Lime.....	12	—	27·1	13·55
Soda.....	9	14·1	—	7·05
Water	5	8·1	4·3	6·20
	99	100·0	99·9	99·95

It will be seen that the Plas Newydd mineral agrees fairly well with the composition of analcime half-converted into prehnite. That such a mineral as analcime should be formed as a true contact-alteration product appears at first very improbable, but the whole process of development can be seen in the specimens, and is precisely similar to that of the garnets.

Moel-y-don and Plas-Coch dykes.—Several dykes, one forty feet in width, were noted by Henslow at Moel-y-don, opposite what is now Port Dinorwic. These are not marked by the Geological Survey, and I have failed to find any exposures on the shore. Others occur inland on about the same line, near Plas-Coch.

[563.] Amygdaloidal dolerite from one of the minor dykes, south of Moel-y-don: a medium-grained ophitic dolerite, with numerous spherical cavities, averaging 0·1 inch in diameter, filled with secondary minerals, and others larger and more irregular in shape. Under the microscope the dominant felspars are seen in elongated sections with ragged ends due to some of the twin-lamellæ projecting beyond others. Between crossed Nicols they show for the most part finely repeated albite-twinning, and some zonary shading. Some sections perpendicular to the twin-plane give extinction-angles up to about 38°, indicating anorthite. The smallest crystals are once twinned, and in several places have a radiate arrangement about a centre. Besides these earlier-formed felspars, there is a second generation, less abundant and, judging roughly from their

[1] Blum., "Pseudomorphosen," p. 100, etc.

extinctions, of a more acidic species. These are untwinned, and show the zones of growth very clearly. They are without crystal boundaries, and sometimes include little crystals of the older generation. Magnetite occurs in small cubes of later formation than the first set of felspars: it is not very abundant. The augite in pale-brown patches moulds or completely includes the felspars of the earlier generation. In some places it is crowded with short black rods, probably of magnetite, disposed parallel to two definite directions: this appears to be a secondary phenomenon connected with the decay of the augite. The usual feebly polarizing 'viridite' patches replace this mineral, and there is some calcite dust in the slide. The infilling of the vesicles has taken place in several distinct stages. First a zeolitic mineral has been deposited at points on the wall, in fan-like bundles of imperfect crystals. The interior of the cavity, thus reduced in size, has been stained by a greenish-yellow substance, and then lined with chalcedony in the usual mamillary coating. The remainder of the vesicle has finally been filled with calcite, not in one mass, but as a mosaic of distinct crystalline grains, mostly untwinned. In some cases a little clear quartz occurs with the calcite.

Llanddwyn dykes.—Henslow collected specimens from two dykes in the island or peninsula of Llanddwyn, westward of the opening of the Menai Straits. They do not agree in position with those marked on the Survey Map. The rock is much decomposed, and only one slide has been prepared.

[684.] Porphyritic dolerite from Llanddwyn.—This is a fine-grained, much-weathered rock inclosing liver-coloured felspars more than an inch in diameter. One of these is shattered, but the parts still remain in proximity to one another. The microscope shows abundant cubes of magnetite, small felspar prisms much altered, and augite replaced by the characteristic pale-green product with some calcite. There is a small vesicle filled by a deposit of quartz followed by calcite with polysynthetic twinning. The large porphyritic felspars are deeply affected by an apparently saussuritic alteration. In some places, however, they are clear enough for their finely repeated twinning to be made out, and the extinction-angles are such as would be given by labradorite. Similar felspars occur in the Glan Adda dyke already mentioned.

All the dykes of the Menai Straits, with perhaps the exception of the olivine-bearing rock of Plas Newydd, are intermediate rather than basic in their affinities. The characters of the augite are in accordance with this; so also the frequent cross-twinning in the larger felspars and their very pronounced zones of growth, the abundance of magnetite to the exclusion of ilmenite, and the nature of the ground-mass where it occurs. The rocks are all 'porphyritic' in the sense of Rosenbusch, since they contain felspars of more than one generation. When the later felspars occur as microlites forming part of a ground-mass, I have used the name *augite-andesite*. Rocks of more holocrystalline type, in which the two sets of felspars are of about equal size, have been called *dolerites*, as distinguished from

diabases, which are characteristic of larger intrusive masses, and exhibit the 'granular' structure of Rosenbusch. The term *porphyritic dolerites* has been applied to those containing larger scattered felspars, making in all three generations.

The dykes of the central and northern portions of Anglesey and of Holyhead Island differ widely from those described above, and may furnish the subject of further notes.

REVIEWS.

I.—The Fossil Fishes of the Chalk of Mount Lebanon, in Syria. By James W. Davis, F.G.S., F.L.S., etc. Scientific Trans. Royal Dublin Soc., series 2, vol. iii. pp. 457–636, pls. xiv.–xxxviii. (April, 1887.)

AGAIN we have to welcome from the pen of Mr. James W. Davis an important contribution to our knowledge of the palæontology of Fishes. Nearly four years ago (Geol. Mag. Nov. 1883) we received an exhaustive monograph upon the fossil fish-remains of the Carboniferous Limestone of Britain, in which were figured and described a number of teeth and spines, indicative of types previously unknown to science; and on the present occasion, a still more substantial contribution is made in the form of figures and descriptions of a large series of the most perfectly preserved fossil fishes that have hitherto been discovered. The author treats of the palichthyology of the Upper Cretaceous rocks of the Lebanon, as revealed by the researches of the Rev. Prof. E. R. Lewis, formerly of the Syrian Protestant College, Beyrout, whose magnificent collection was acquired some years ago by Mr. R. Damon, of Weymouth, and a large portion of which has now been purchased by the British Museum. This memoir, like the previous one, was communicated by the late Earl of Enniskillen to the Royal Dublin Society, and is printed and published in the excellent style for which that Society's Transactions are so well known.

On glancing over the pages, we are led to admire the industry and untiring energy of the author, who succeeds, in the midst of business avocations and at so great a distance from works of reference, in turning hours of leisure to such profitable account. Nearly all the more important memoirs bearing upon the subject have been consulted and are referred to, and, in addition to notes upon forms already known, no less than ten genera and sixty-six species are described as new to science. At the same time, the pursuit of scientific study under such conditions must necessarily render one liable to errors arising out of the very difficulties surrounding work requiring so much research as the present; and to this cause must probably be ascribed certain misapprehensions that will doubtless be criticized adversely by ichthyologists more favourably situated for interpreting these remains.

Mr. Davis prefaces his work with a concise and appropriate introductory section, historical and geological. This is mainly based